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RADII OF OPTICAL-MODEL POTENTIALS IN PROTON SCATTERING AT 183 Mev

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Previous analyses[1,2] of the elastic scattering of 150-300 Mev protons by nuclei using the optical model of the interaction have shown that it is able to give a good account of the existing experimental differential cross sections and polarizations. In most cases, however, the experimental data do not extend much beyond the first diffraction minimum, and so do not accurately determine the parameters of the optical-model potential.

Recently, Johansson and Svanberg[4] have made a series of accurate measurements of 183-Mev protons elastically scattered by a range of eight nuclei from lithium to gold. Particular care was taken to eliminate inelastically scattered protons, and the differential cross sections were obtained out to around 70°. Measurements of the reaction cross sections were also made and these, combined with the existing polarization data, make a more complete set of data for optical-model analysis than has hitherto been available. We have found that the elastic scattering and polarization can be simultaneously well described only if the imaginary part of the optical-model potential is given a significantly greater radius than the real part.

The optical-model potential was taken to have the usual form,

$$V(r) = V_{\mathrm{Coul}}(r) + Uf_1(r) + iW[\alpha f_2(r) + (1-\alpha)g(r)] + \left(\frac{\hbar}{m_\pi c}\right)^2 \left[U_s \frac{df_3(r)}{dr} + iW_s \frac{df_4(r)}{dr}\right] \frac{1}{r}\vec{l}\cdot\vec{\sigma},$$

where $f(r)$ and $g(r)$ are Saxon-Woods and Gaussian form factors, and the other symbols have their usual meanings.[4] All calculations were done on the Oxford University Mercury computer using methods described elsewhere.[5]

Preliminary attempts to fit the data were concentrated on aluminum, partly because it is a fairly light nucleus and partly because the difference between the experimental data and previous optical-model calculations at[2] 160 Mev is greatest for this nucleus.

The most striking feature of the experimental differential cross section [Fig. 1(a)] is the virtual absence of oscillatory structure, in sharp contrast to the considerable oscillations shown by the optical-model cross section with the potentials used previously. This effect is most marked beyond the first minimum and so has not been noticed previously. The absence of oscillations cannot be attributed to experimental smearing, as particular care was taken to achieve good angular (± 0.4°) and energy (± 0.5-Mev) resolution.

The first aim of the present work was to resolve this discrepancy. To facilitate comparison with previous work, as many parameters as possible were kept the same as before. The starting potentials were taken to be $U = -18$, $W = -12$, $U_S = 2.5$, $W_S = -1$ Mev, and all radii were fixed at $R = 1.25\,A^{1/3}$ f, with diffuseness parameters $a = 0.65$ f and $b = 1.0$ f for the Saxon-Woods and Gaussian form factors. With $\alpha = 1$, corresponding to a Saxon-Woods absorption potential, the parameters U, W, a_1, a_2, and $a_3 = a_4$ were varied to see if the oscillations could be removed, but without success. Further calculations were made with the Gaussian form for the absorbing part of the central potential, and with an equal mixture of Gaussian and Saxon-Woods forms ($\alpha = 0.5$). In each case the differ-

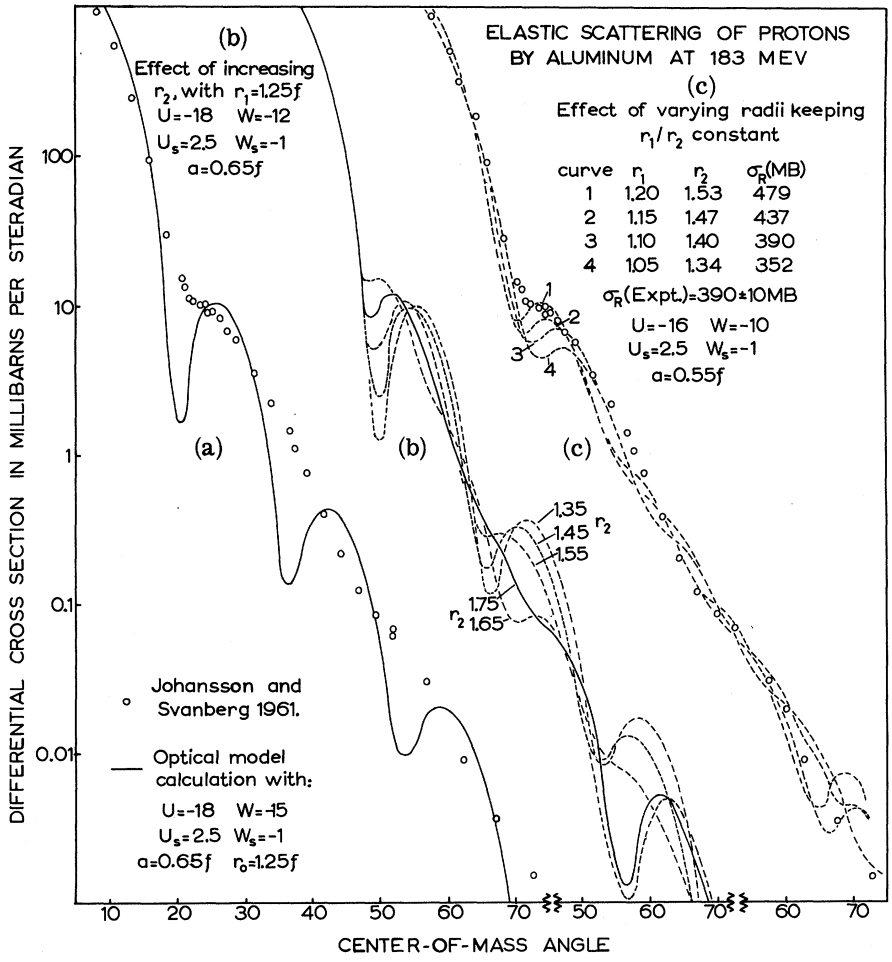

FIG. 1. (a) Experimental differential cross sections for the elastic scattering of 183-Mev protons by aluminum compared with an optical-model calculation with equal radii for the real and imaginary parts of the potential. (b) Calculated differential cross sections for the same interaction with increasing values for the radius of the absorbing potential. (c) The same for a series of radii, with $r_2 = 1.27\, r_1$.

ential cross sections showed substantial oscillations, in disagreement with the experimental data.

The effect of different radii for the real and imaginary parts of the potential was then studied. Keeping the radius of the real part at $r_1 = 1.25$ f, the radius of the absorbing part r_2 was varied from 1.25 to 1.75 f for the Saxon-Woods form factor ($\alpha = 1$). Figure 1(b) shows that when $r_2 = 1.75$ f, the differential cross section falls smoothly with angle from 25° to 55°, like the experimental data. This value of the radius, however, gives too large a value for the reaction cross section. The radii were, therefore, progressively reduced in the same ratio until the reaction cross section attained approximately the correct value; this happens when $r_1 = 1.10$ f, and $r_2 = 1.40$ f. The results of these calculations are given in Fig. 1(c), and show that the smooth fall of the differential cross section is retained. The slight oscillation around 20-30° is qualitatively given by the model, and it is convenient to adjust the radii until the maximum of this oscillation has the experimental value. The reaction cross section can be brought back to the correct value by adjusting W, the strength of the absorbing potential. Similar calculations were made for $\alpha = 0$ and $\alpha = 0.5$, but in all cases the differential cross section showed oscillations greater than those observed experimentally. In all this work the radii of the spin-orbit potentials r_3 and r_4 were kept equal to the radii of the corresponding central potentials r_1 and r_2, respectively.

If the polarization given by the best of these potentials is compared with experiment (Fig. 2), it is found to have the required minimum around 23° that was not given by any potentials with $r_1 = r_2$. The calculated minimum is rather deeper than the experimental, but it is possible that adjustment of the spin-orbit potentials could remove the remaining discrepancy. Thus in fitting

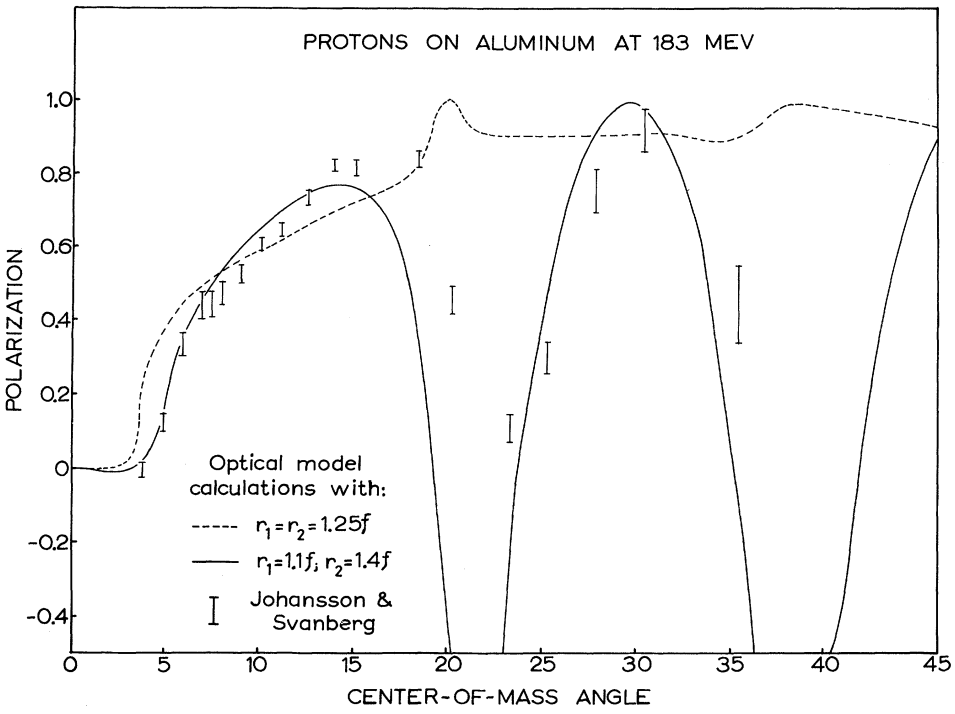

FIG. 2. Experimental polarization for the elastic scattering of 183-Mev protons by aluminum, compared with the optical-model calculations using the same potentials as in Figs. 1(a) and 1(c) (Curve 3).

the differential and reaction cross sections the most serious polarization discrepancy has been removed as well.

These potentials were then used to calculate the cross sections and polarizations for the remaining nuclei Li, Be, C, Ca, Fe, In, and Au, and in each case good qualitative agreement with the experimental data was found. In particular, the smooth fall of the differential cross section is well reproduced. For each of these interactions the fit to the experimental data can be improved by systematic fine adjustment of the parameters. This work is still in progress and will be reported on completion.[3]

Although the parameter space has not been completely explored, the present preliminary work thus suggests that in energetic proton interactions with medium-weight nuclei the absorbing part of the local potential extends some 30% beyond the real part, and that it is similar to the Saxon-Woods form.

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